ICEC/ICMC

25th International Cryogenic Engineering Conference & International Cryogenic Materials Conference 2014

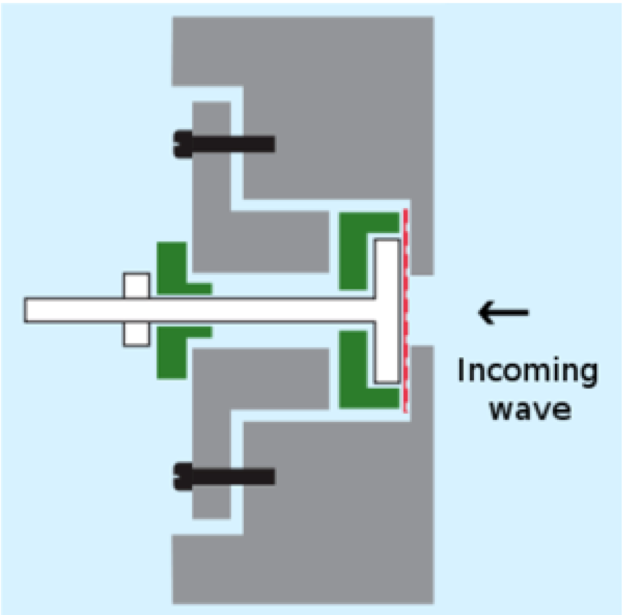
On the Mystery of using Helium's Second Sound for Quench Detection of a Superconducting Cavity

R.Eichhorn#, S. Markham, CLASSE, Cornell University, Ithaca, NY 14853, USA

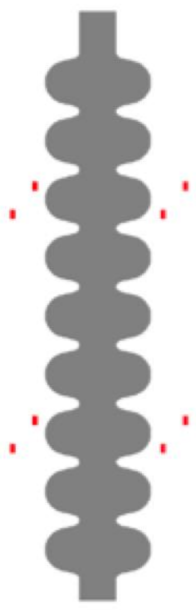
Abstract

The detection of a second sound wave, excited by a quench, has become a valuable tool in diagnosing hot spots and performance limitations of superconducting cavity. Several years ago, Cornell developed a convenient detectors (OSTs) for these waves that nowadays are used world-wide. In a usual set-up, many OSTs surround the cavity and the quench location is determined by triangulation of the different OST signals. Convenient as the method is there is a small remaining mystery: taking the well-known velocity of the second sound wave, the quench seems to come from a place slightly beyond the cavity's outer surface. We will present a model that might help explaining the discrepancy.

Quench Detection using 2nd sound in Helium-II



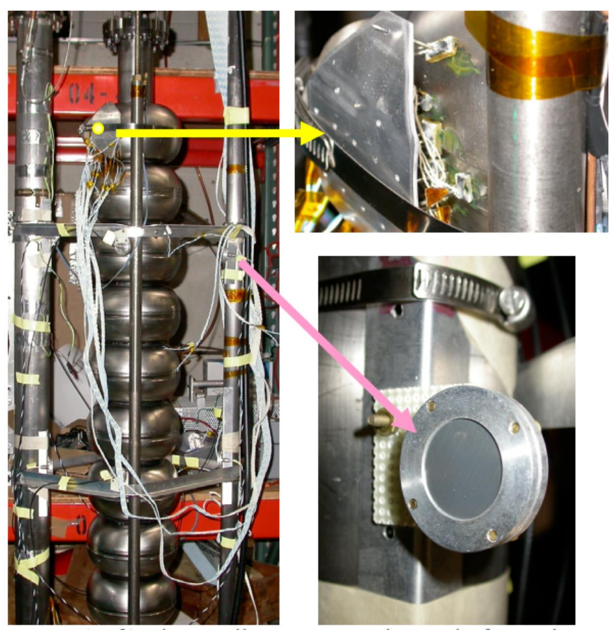
OST (Oscillating Superleak Transducer)

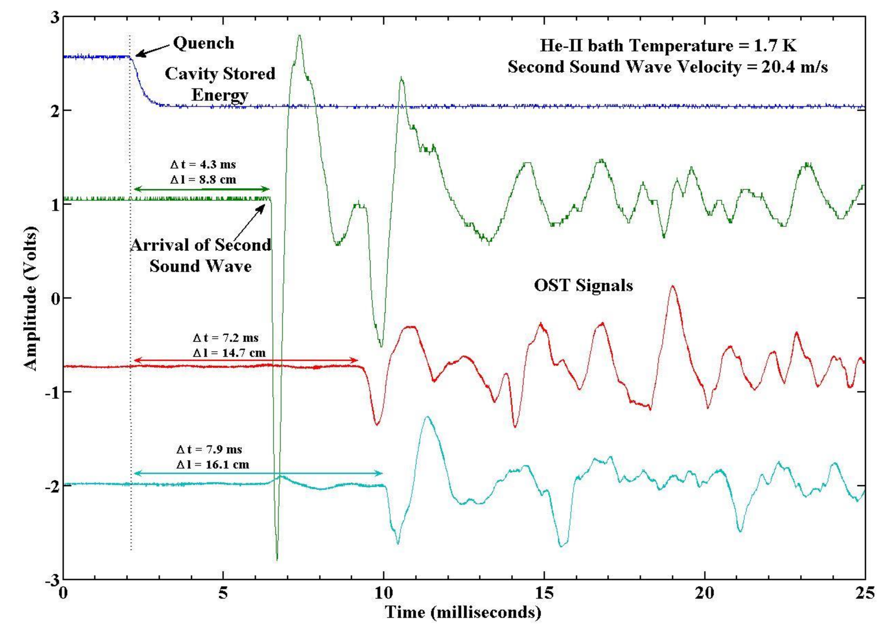


The method:

- Second sound wave produced
- Second sound wave propagates
- Second sound wave detected
- Quench location triangulated

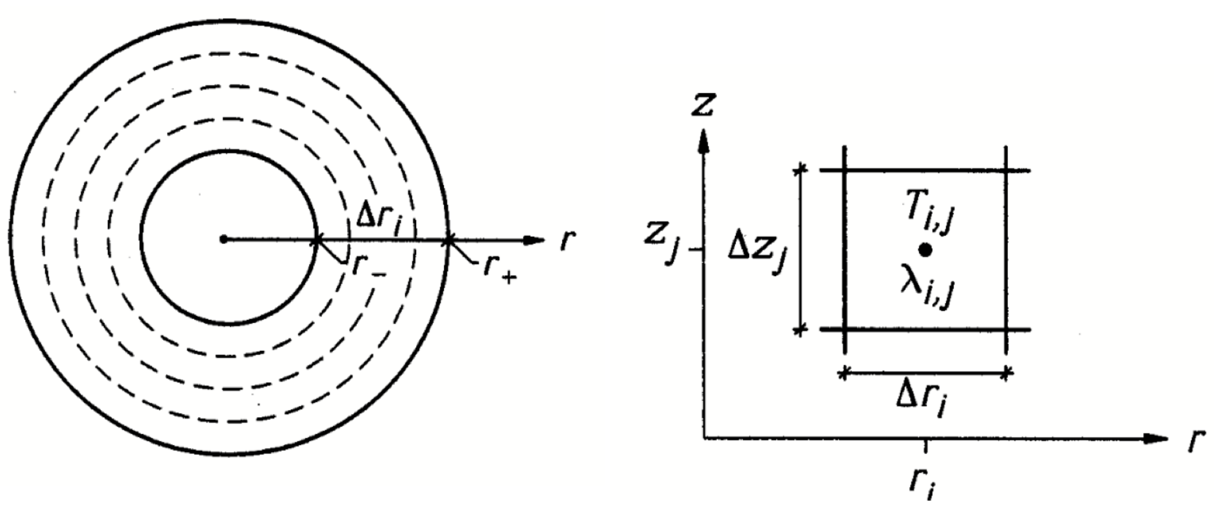
- Problem: quench location often found to be off of cavity surface
- Potential explanation: second sound produced before noticeable loss of energy





Experimental Set-up and typical Data Set)

Numerical Model



Time-Step: $\Delta t < \frac{C_{ij} 2\pi r_i \Delta r \Delta z}{K_{i-1,j} + K_{i+1,j} + K_{i,j-1} + K_{i,j+1}} \; \forall\, i,j$

Discretization: $K_{i,j-1} = \frac{2\pi r_i \Delta r}{\Delta z (k_{i,j-1} + k_{i,j})/2}$

$$K_{i-1,j} = \Delta z \cdot \left(\frac{\ln(r_i / r_{i-0.5})}{2\pi k_{i-1}} + \frac{\ln(r_i / r_{i+0.5})}{2\pi k_i} \right)^{-1}$$

Loss Calculation: $P_{diss} = \frac{1}{2} A R H^2$

$R_n = \sqrt{\frac{\omega \mu_0}{2\sigma}}$ $\qquad R_s = R_0 + R_{BCS}$

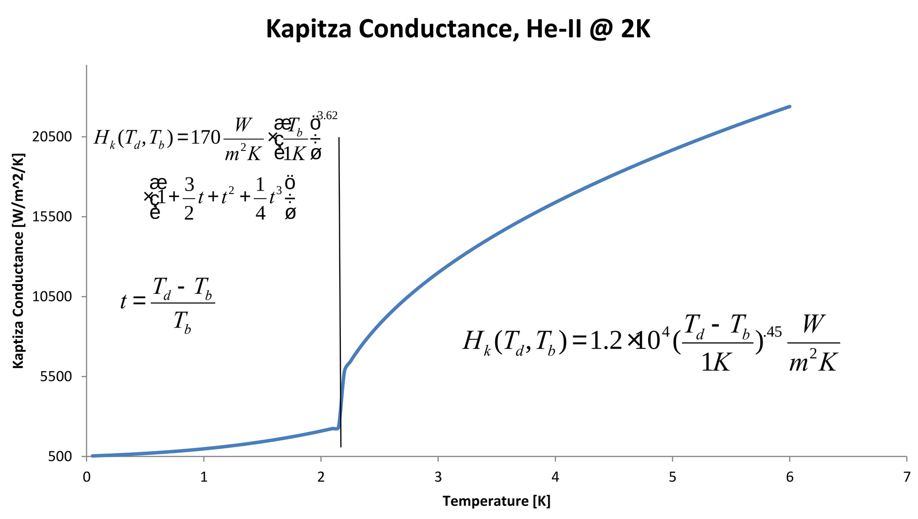
$$R_{BCS} = (2.78 \cdot 10^{-5}\,\Omega) \frac{\nu^2}{\tau} \ln \frac{148\tau}{\nu} \exp - \frac{1.81 g(\tau)}{\tau}$$

$$\tau = \frac{T}{T_c};\ \nu = \frac{f}{2.86 GHz};\ g(\tau) = \sqrt{\cos \frac{\pi \tau^2}{2}}$$

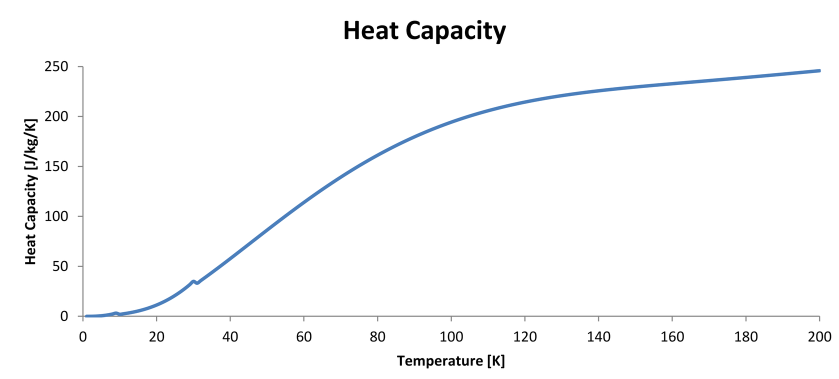
Assumptions:

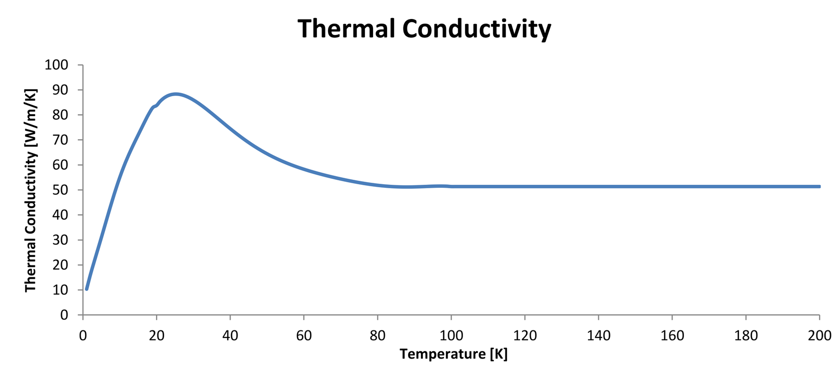
- Niobium disk (r=8mm, z=2mm), RRR=300
- Bath temperature is 2K
- RF magnetic field is 1×10^5 A/m
- Minimal heat flux to trigger 2nd sound wave: 1.5W/cm²
- Lower detectable RF power drop: 2%
- Initial quench spot size: 0.2 mm

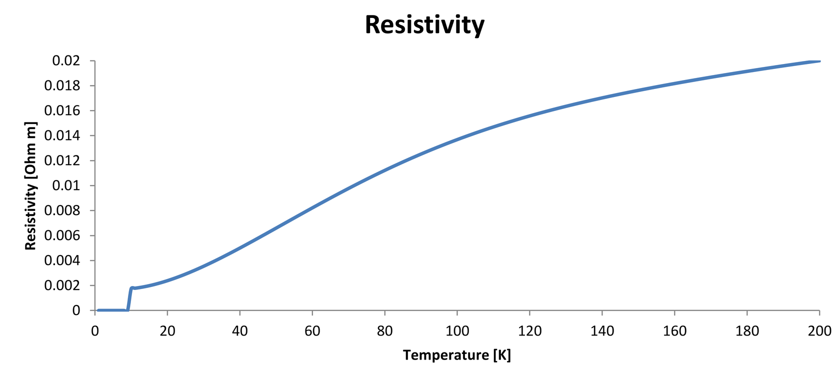
Kapitzka Resistance



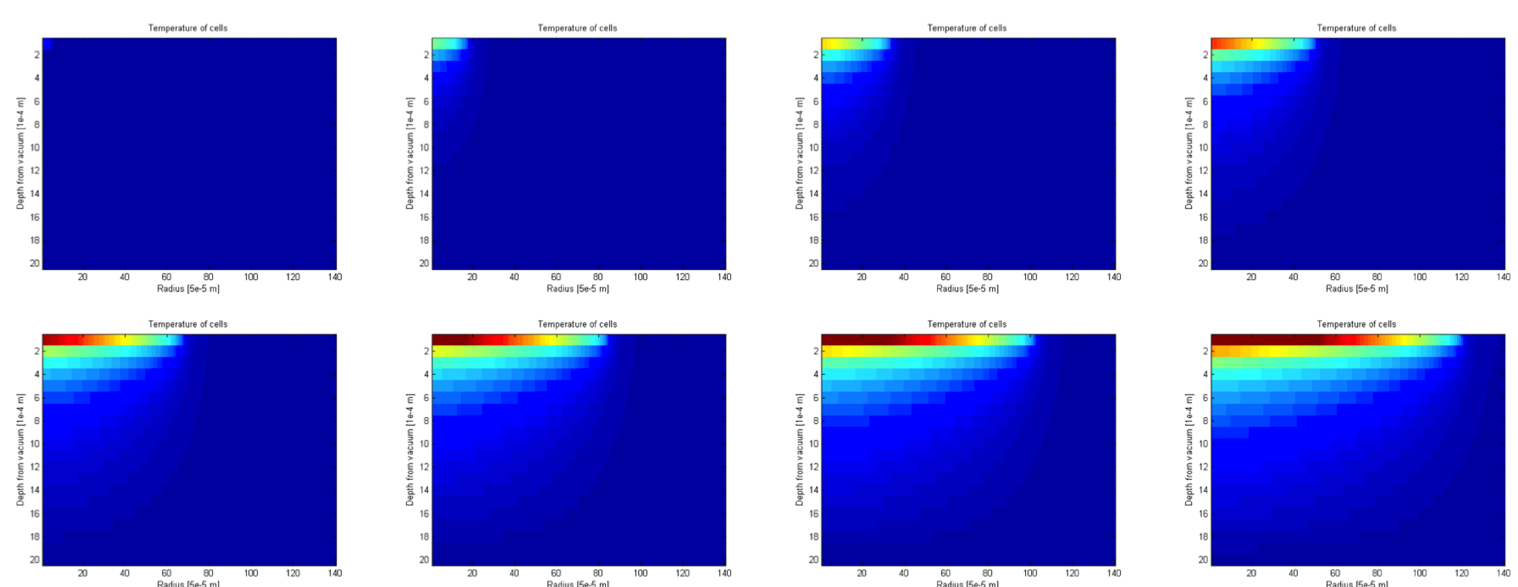
Cryogenic Data Set



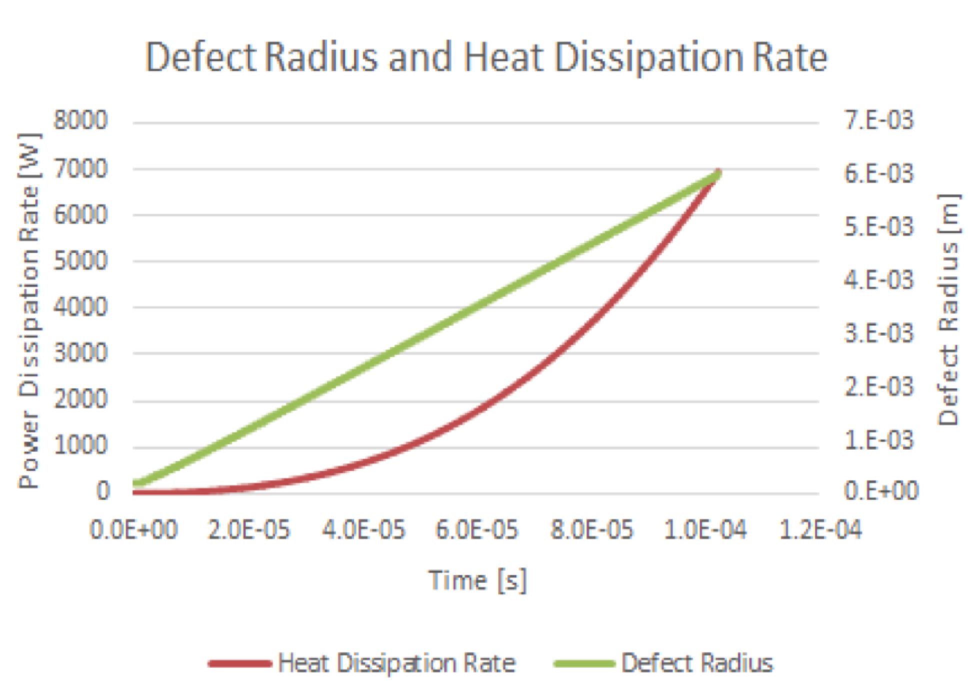




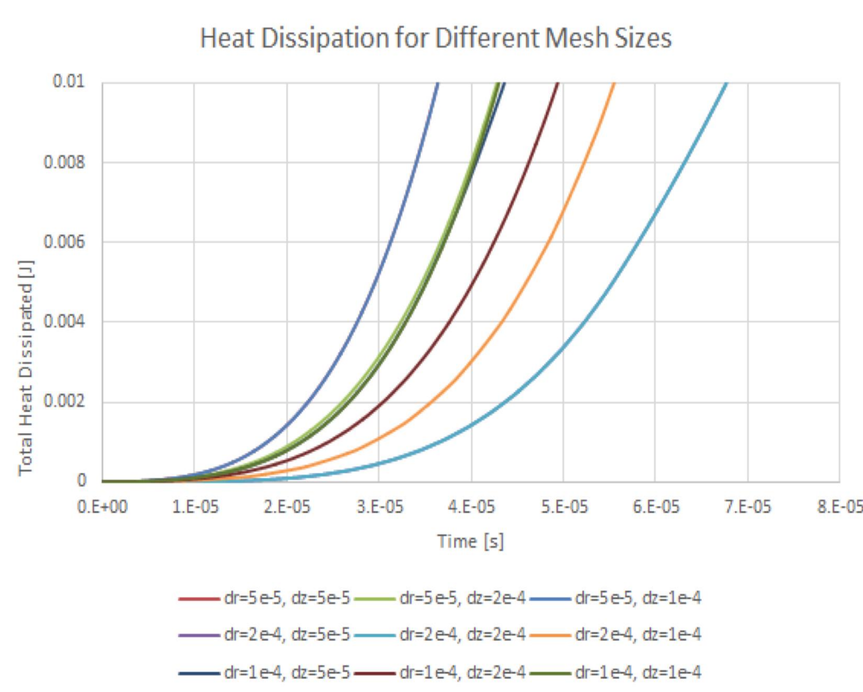
Quench Propagation



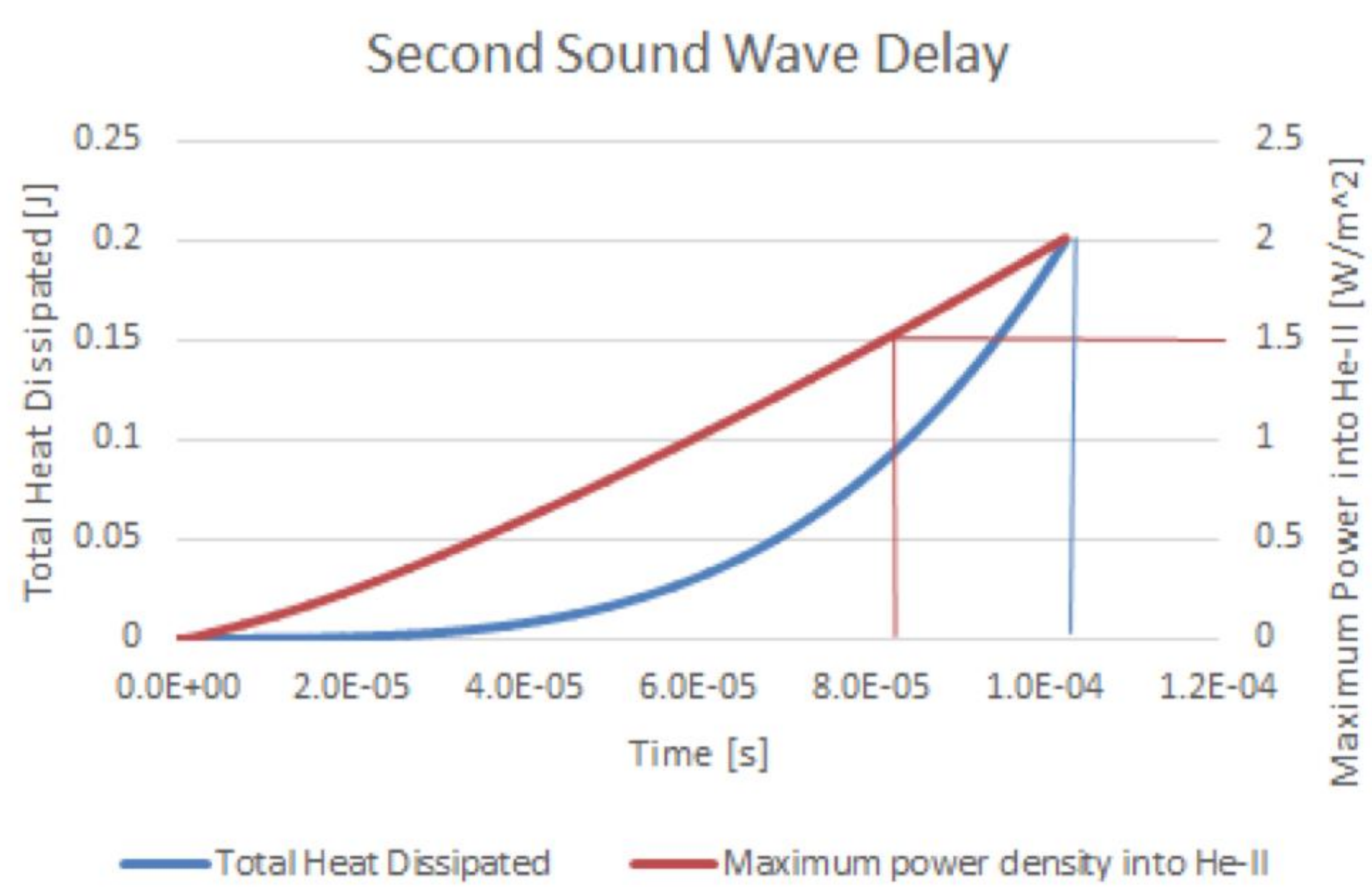
Quench Spot Growth



Convergence Check



Power Dissipation and Second Sound Wave



Conclusion

Even with very conservative assumptions we found that the second sound wave of significant amplitude is generated before the quench is detectable from the RF side.

We calculated a delay in the order of 10's of μs (depending on the assumptions) corresponding to 2-5 mm in distance. This explains well the findings named as the circle of uncertainty which we think can be explained with our model.

CLASSE facilities are operated by the Cornell Laboratory for Elementary Particle Physics (LEPP) and the Cornell High Energy Synchrotron Source (CHESS) with major support from the National Science Foundation.